Rocky Mountains

Southwest

Great Plains

**Research Note RM-404**

June 1981



USDA Forest Service

Rocky Mountain Forest and Range Experiment Station



# Variation in Growth of Engelmann Spruce Seedlings Under Selected Temperature Environments

**Wayne D. Shepperd**[1]



Seedlings grown with soil temperatures kept higher than air temperatures in the daytime and with soil and air temperatures kept equal at night produced significantly longer and heavier roots than seedlings grown under conditions previously considered optimum (i.e., soil and air temperatures both higher at night than in the daytime).

**Keywords:** *Picea engelmannii*, tree physiology, containerized seedlings

## Management Implications

This study has demonstrated that, under specific, controlled environments, growth of Engelmann spruce (*Picea engelmannii* Parry) seedlings does respond to relatively slight changes in air and soil temperatures. Seedlings grown for 14 weeks in a regime where daytime soil temperature was higher than air temperature produced slightly larger tops and significantly larger roots than seedlings grown under a regime in which air and soil temperature were not varied.

This study provides a possible means of increasing the growth rate of commercially produced, containerized Engelmann spruce planting stock by closely regulating root temperature. These techniques could be used in commercial greenhouse operations either to produce larger seedlings or to shorten the greenhouse production cycle.

## Introduction

Engelmann spruce is a primary timber species in the central Rocky Mountains. While current silvicultural management is directed toward regenerating the species naturally, through even-aged shelterwood cutting methods (Alexander 1974), a substantial reforestation backlog exists in areas which were clearcut in the 1960's and early 1970's. Traditionally, Engelmann spruce has been artificially regenerated by planting nursery grown, bare-root stock. However, 3 years are needed to produce trees large enough for field planting. Under current economic conditions, this is becoming more expensive. Therefore, the production of containerized stock, in controlled environments, is becoming a viable alternative (Colby and Lewis 1973). Hellmers et al. (1970) studied the growth of Engelmann spruce under controlled environments, and found the temperature combination producing the greatest height growth and dry matter production was a diurnal variation of 19° C day temperature and 23° C night temperature. Because air and soil temperatures were the same, the role of soil temperature alone in increasing Engelmann spruce seedling growth was not evaluated.

The influences of soil temperature on growth of plants has long been established. Studies of coniferous tree species have shown that growth of redwood and ponderosa pine can be enhanced by maintaining soil temperatures equal to or greater than air temperatures (Hellmers 1963, Larson 1967), while optimum growth of white spruce requires soil temperatures to be slightly less than air temperature (Heninger and White 1974).

The effect of temperature on the growth of Engelmann spruce has not been investigated under conditions where soil temperatures have been controlled independently of air temperatures. Therefore, this study was made to determine the growth of Engelmann spruce seedlings under four combinations of day-night and air-soil temperatures.

[1]*Associate Silviculturist, Rocky Mountain Forest and Range Experiment Station; headquarters is in Fort Collins, in cooperation with Colorado State University.*

## Methods

Because of limited facilities, treatment selection was restricted to several combinations of day and night air and soil temperatures, based on results of Hellmers et al. (1970).

Treatments chosen for comparison are shown in table 1.

Table 1.—Treatments used

| Treatment | Temperature (° C) Day Air | Day Soil | Night Air | Night Soil |
|---|---|---|---|---|
| 1 | 19 | 19 | 23 | 23 |
| 2 | 19 | 23 | 19 | 23 |
| 3 | 19 | 19 | 19 | 23 |
| 4 | 19 | 23 | 23 | 23 |

Treatment 1, identical to Hellmers' et al. (1970) combination for best Engelmann spruce growth, served as an optimum bench mark to compare with effects of other treatments. Treatment 2 was an air-soil temperature differential with no diurnal variation in temperature; it was chosen to isolate any effect of air-soil temperature from day-night temperature. Treatments 3 and 4 provided additional contrasts of air-soil and day-night temperatures. These treatments were not in conflict with Hellmers' et al. earlier study, because a daytime air temperature regime was maintained which was less than or equal to the nighttime air temperature.

Seeds selected from a standard nursery seed lot were germinated in a germination cabinet then transferred to controlled environment growth chambers for the 14-week treatment period. Seedlings in all four treatments were grown in 1.25-liter pots, in a medium of coarse sand and perlite, and were watered daily with half-strength Hoaglands nutrient solution. A 16-hour photoperiod of 2,500 fc artificial light and a relative humidity of 80-90% were also standard. Because two germinator runs were required to supply enough seedlings, a randomized block design was used, with each treatment replicated twice. Each replication consisted of two pots containing 10 seedlings each.

Temperature was the only environmental parameter which was varied. Air temperature was kept within ±1° C in the growth chambers. An electrically heated, laboratory water bath was modified to provide the 23° C soil temperature treatment when needed.

After 14 weeks of growth, seedlings were carefully washed from the pots, total shoot height and shoot height above the cotyledons were measured, and the number of primary branches and lateral buds were recorded. Root length for each seedling was measured as a distance from the root collar to the tip of the longest root. Shoots and roots were then separated at the root collar, placed in separate weighing cans, and oven dried for 24 hours at 100° C before weighing. Oven dry weights were used to calculate root-shoot ratios. Pot averages were analyzed using a randomized block analysis of variance. A Tukey's Multiple Range Test was used to compare treatment means. These differences were significant at the 95th percentile ($P = 0.05$).

## Results

The analysis revealed significant treatment differences for every variable measured (table 2). Treatments 1 and 4 produced seedlings with larger, heavier tops and larger total dry weights than seedlings grown under other treatments. No statistical difference was shown for root length and root dry weight between treatment 1 and treatments 2 and 3. However, root lengths and dry weights of treatment 4 seedlings were significantly greater than seedlings of the other three treatments.

## Discussion and Conclusions

The significant improvement in root growth of seedlings in treatment 4 over those of the previously known optimum in treatment 1 suggest that the 23° C daytime soil temperature favored root development. While only root growth in treatment 4 was significantly greater than in treatment 1, the 23° C daytime soil temperature produced an overall larger seedling. This most likely had several physiological effects on growth of Engelmann spruce seedlings. The increase in soil temperature over the 19° C in treatment 1 probably caused a slight decrease in hydraulic resistance to absorption of water and nutrients by the roots, and an increase in root metabolic rate, which may have resulted in the increased root growth. Any increased uptake of water by roots would result in more favorable water potentials throughout the plant.

Apparently, soil temperatures higher than air temperatures benefit Engelmann spruce only during the day. The nighttime air-soil temperature differential in treatments 2 and 3 produced significantly less shoot growth than in treatments 1 and 4, which had no air-soil differential at night.

Some variation in growth was apparent among seedlings within each treatment (fig. 1). Because all environmental parameters were carefully controlled in this study and the variation was noticeable even among seedlings growing in the same pot within a treatment, it would seem that genetic diversity is responsible. Under current conditions, it is not economically practical to raise Engelmann spruce seedlings which will have to be culled at the end of an expensive greenhouse program.

Additional research by geneticists, silviculturists, and physiologists is needed to determine whether selection of seed from superior seed sources will eliminate or reduce this variation in growth under controlled environments, and whether seedlings, which grow best under optimum conditions in the greenhouse, will survive best when planted in the field.

Table 2.—Average Engelmann spruce seedling production after 14 weeks of growth[1]

| Treatment | | Temperature regime Day | Temperature regime Night | Total shoot height | Shoot height above cotyledons | Length of roots | Number of primary branches | Shoot weight | Root weight | Total seedling weight | Root/shoot ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ° C | | millimeters | | | | milligrams (oven dry) | | | |
| 1 | Air | 19 | 23 | $53.0_a$ | $41.7_a$ | $172.9_b$ | $3.9_a$ | $118.6_a$ | $50.5_b$ | $169.1_a$ | $0.44_b$ |
| | Soil | 19 | 23 | | | | | | | | |
| 2 | Air | 19 | 19 | $31.3_b$ | $20.0_b$ | $155.4_b$ | $2.1_b$ | $69.2_b$ | $49.4_b$ | $118.6_b$ | $0.89_a$ |
| | Soil | 23 | 23 | | | | | | | | |
| 3 | Air | 19 | 19 | $37.0_b$ | $25.5_b$ | $170.8_b$ | $2.0_b$ | $79.2_b$ | $48.0_b$ | $127.2_b$ | $0.75_{ac}$ |
| | Soil | 19 | 23 | | | | | | | | |
| 4 | Air | 19 | 23 | $57.4_a$ | $45.3_a$ | $210.0_a$ | $4.6_a$ | $120.3_a$ | $67.2_a$ | $187.6_a$ | $0.59_{bc}$ |
| | Soil | 23 | 23 | | | | | | | | |

[1] *Values within each variable having identical letters are statistically homogeneous at the 95th percentile (Tukey's Test).*

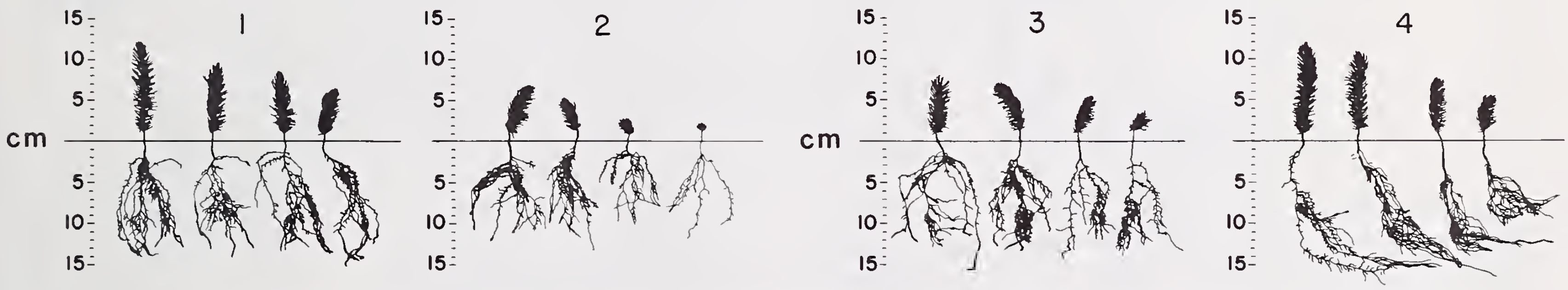


**Figure 1.—Comparison of top and root development of seedlings from each treatment. The large variation in seedling size within each treatment is quite apparent, as are the longer roots of treatment 4 seedlings.**

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Agriculture—CSU, Fort Collins

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